# Ice Penetrating Communication Buoy for Underwater Vehicles Operating in the Arctic

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## LONG TERM GOALS

Our long-terms goals are to develop an ice penetrating communication buoy for use in the Arctic. The buoy will be launched by the underwater vehicle, float to the surface, melt thought the ice, deploy antennas, and communicate via satellites. The long-term goals include providing two-way communications between the underwater vehicle and the buoy.

## OBJECTIVES

The immediate objective is to provide a way for the ALTEX (Atlantic Layer Tracking Experiment) UUV to transmit its data back and obtain navigation fixes to ground-truth the data. The purpose of the ALTEX vehicle is to perform long-range missions in the Arctic to collect environmental data relative to global warming. Data would be downloaded to the communications buoy roughly once per day. The buoy would then be launched, melt through the ice, obtain a GPS fix, and transmit the data and GPS fix back via ARGOS. The effort conducted by SSI under this contract also includes development and fabrication of the launcher to transfer data to the buoys and eject the buoys. The entire system will be tested in the Arctic in October 2001.

## WORK COMPLETED

A. Communication Buoy:

Fig. 1 shows the entire buoy. Buoy diameter is 3.5 in. and length while carried in the AUV is 4 ft. After release, and just prior to melting through the ice it expands to 6 ft. long. From the rear of the buoy forward are the buoyancy/ballasting section, the pump housing section, the pressure hull section, the acid storage section, the antenna balloon section, and the melter head section.

Fig. 2 shows the buoyancy/ballasting section. It consists of three syntactic foam pieces surrounding a spring-loaded extension rod with a counter- weight at the end. The syntactic foam causes the buoy to be slightly buoyant prior to launch. Just prior to the melting process, the buoy extends itself, which extends the counterweight and releases the foam. Together with the increased buoyancy towards the nose that is discussed below, this results in a strong righting moment.

Fig. 3 shows the pump housing section and pressure hull section. The pump forces seawater through a short section of stainless steel tubing and a longer section of coiled rubber tubing, into the melter head section. Also located in the pump housing section is an inductive coil for communications between the buoy computer and the launcher computer. The launcher computer communicates in turn with the main vehicle computer.

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14. ABSTRACT
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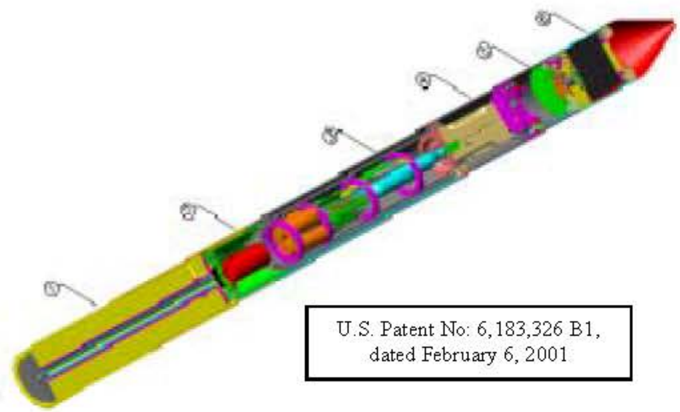


***Fig. 1. The ice penetrating communications buoy in the retracted state. From the rear forward are the buoyancy/ballasting section (1), the pump housing section (2), the pressure hull section (3), the acid storage section (4), the antenna balloon section (5), and the melter head section (6).***

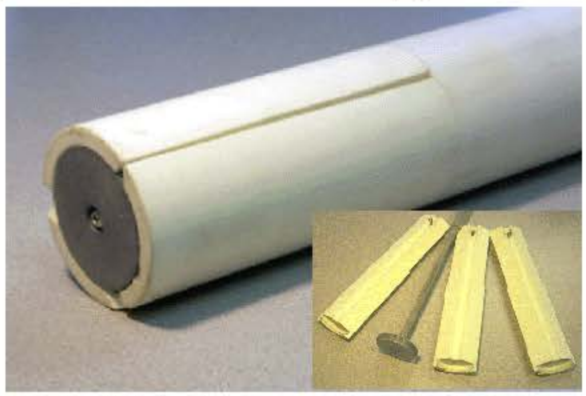

***Fig. 2. Ballast/buoyancy section of the buoy.***

Within the pressure hull are 4 lithium C-cell batteries, a Tattletale Model 8 computer, an ARGOS transmitter, a Persistor memory board, a GPS receiver and a custom interface and control board. Also within the pressure hull is a pressurized nitrogen canister that provides expansion gases to both extend the buoy and inflate the antenna balloon. Inserted into the top of the pressure hull is a squib actuator that punctures the nitrogen canister on command from the computer. When punctured the nitrogen gas fills the cavity outside and above the pressure hull, causing the outer shell of the buoy to slide along the pressure hull. This extension of the buoy results in a large increase in buoyancy towards the top of the buoy. It also releases the syntactic foam pieces, and extends the counter weight.

Acid is stored in the coiled tube shown in Fig. 4. The tube is coiled around a cylindrical piece of syntactic foam that adds buoyancy. The tube is connected to the pump and the melter head section. The melt-though process is initiated by briefly pumping seawater to inject the acid into the melter section.

The melter section contains a cylindrical piece of Pyrosolve-Z chemical stored in a rubber bag that is connected to the outlet of the acid storage tube. The chemical is fabricated by Consolidated Technologies in St. Johns, Newfoundland. When the acid is injected, the reaction between acid and chemical heats the chemical. When the Pyrosolve-Z is hot enough, injection of water results in a continuing chemical reaction that generates roughly 1500 W of heat output in the form of steam. (Cold water alone will not initiate a reaction with the chemical.) The steam is funneled out of the buoy through a metal nose cone. The buoy computer monitors a thermistor and controls the flow of seawater to the chemical.


***Fig. 3. Pump housing and pressure hull section. Also shown are the cage and electronics inside the pressure hull, the top of the pressure hull showing the feedthroughs, and the squib device used to puncture the nitrogen cartridge.***

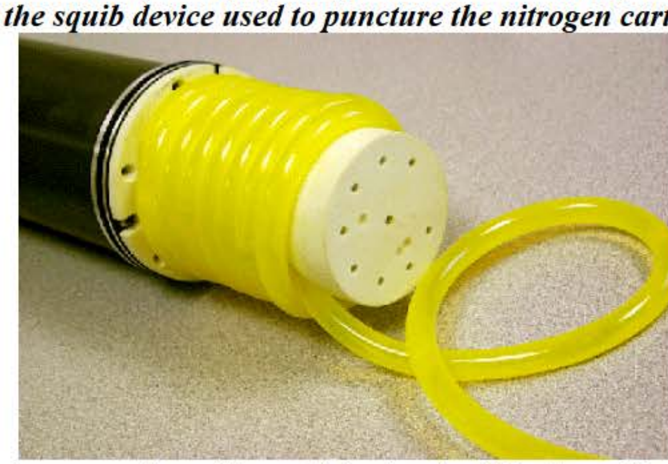

***Fig. 4. Acid storage section. The acid is stored within the yellow tube. One end of the tube is fed from the aluminum tube, the other feeds into the melter section. The acid is delivered to the melter section when the pump first starts.***

The antenna balloon section and the melter head section are shown in Fig. 5. After the nitrogen cartridge is punctured and the buoy extends, the acid storage section cavity remains pressurized while the ice-melting process proceeds. After enough time has elapsed for the melt-through to complete, the computer fires another squib charge, releasing the pressurized gas into the antenna balloon. There is sufficient gas to inflate and fill the antenna balloon. Upon expansion the antenna balloon also presses against a plate that releases the melter head section, which falls away from the buoy.

The buoy in its current design can melt through up to 1 m of ice. U.S. Patent Number 6,183,326 B1, dated February 6, 2001, protects its design.

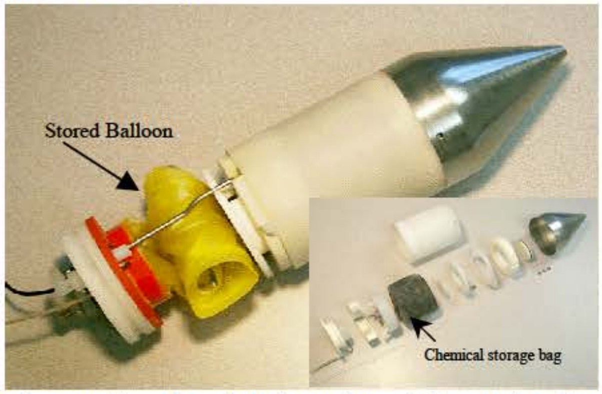


***Fig. 5. Antenna balloon section and melter head section. The melter head section is also shown apart. The chemical used for melt through is stored in the rubber bag. After starting, the flow of seawater by the chemical results in steam that heats the metal nose cone.***

B. Launcher:

The launcher designed for the ALTEX vehicle is shown in Fig. 6. Up to 12 buoys are carried in a rotating carousel. The launcher contains a computer that receives commands from the main vehicle computer, controls the launcher functions, and communicates with the buoys. Communication with the buoys is through an inductive link. The launcher section contains a spring-loaded door and push rods to force the buoys out through the door.

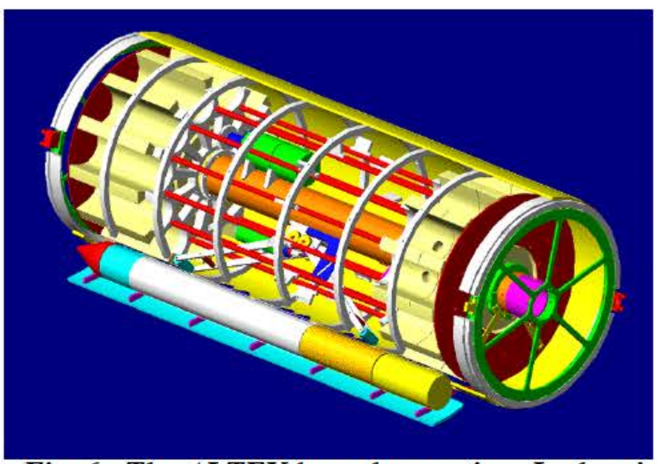
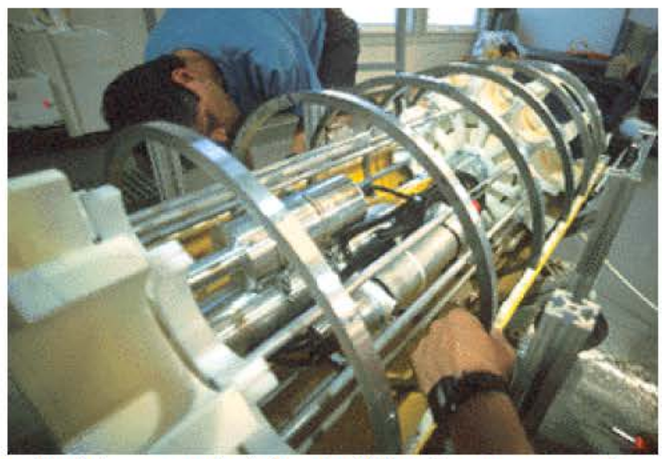

***Fig. 6. The ALTEX launcher section. In drawing and picture, part of the shell has been removed.***

**RESULTS**

BUOY LAUNCH AND MELT THROUGH SEQUENCE:

The launch sequence begins with the AUV sending a large set of oceanographic data to the launcher computer. The launcher then passes the data on to the buoy that is currently in the data download position. In this position the inductive coils of the launcher and the buoy overlap. The buoy in this position is the one that will be launched next. The vehicle then begins a search for thin ice, using its ice mapping sonar to find ice less than 1 m thick.

After thin ice is found, the main vehicle computer commands the launcher computer to launch the current buoy. The launcher computer moves the buoy from the data position to the launch position,

where the buoy is lined up with the launcher door, and then activates the push rods that force the buoy out through the launcher door. At the same time a small weight is dropped from the launcher such that the entire launcher section remains neutrally buoyant. The buoy, being just slightly buoyant, ascends tail-first at approximately 1 m/sec and rests against the bottom of the ice. A launch sequence is shown if Fig. 7.

***Fig. 7. These pictures show the launch of a buoy from the ALTEX vehicle.***

After waiting for an appropriate amount of time for the buoy to ascend to the surface, the buoy computer sets off the first squib actuator, puncturing the nitrogen cartridge. The nitrogen fills and pressurizes the cavity below the antenna balloon, which forces the buoy to expand lengthwise. The syntactic foam pieces at the bottom of the buoy are jettisoned, and the counterweight extends. These changes result in a large increase in buoyancy and righting moment, flipping the buoy around so it rests against the ice in an upright orientation. In this configuration the buoy has approximately 2 lbs of buoyancy and enough righting moment to remain upright in current up to 15 cm/s.

The melt-though process is then started, with pump activation for approximately 12 seconds. The acid flows around the chemical and starts a reaction that rapidly warms the chemical. The computer monitors the chemical temperature, using the thermistor, and starts the seawater pump when the temperature reaches 70°C. The buoy then melts its way up through the ice. To maintain the process the computer continues to monitor the reaction temperature, turning off the pump if the temperature drops below 70°C and restarting it when the temperature exceeds 85°C. The buoy melts through 1 m of ice in approximately 30 minutes.

After 30 minutes the buoy computer assumes the chemical charge is expended, and fires the second squib actuator to inflate the antenna balloon and eject the melter section. The computer then obtains a GPS fix and begins to send back its location and the oceanographic data. Fig. 8 is a pictorial sequence of the melt-through process.

The buoy melt through process was tested in the Arctic in April 1999 [4]. The complete buoy was successfully tested on a lake in Northern Maine in March 2001. The launcher was integrated into the vehicle in June 2001 and successfully tested off the coast of California. Arctic testing of the entire vehicle is scheduled for October 2001 off the USCG Icebreaker Healy.

## IMPACT/APPLICATIONS

An ice penetrating communications buoy and launcher system for an AUV has been developed and tested. The buoy/launcher design could also be used in open waters. Planned modifications of the buoy include packaging it so manned submarines could use it for communications and adding an acoustic modem. The later would allow navigation data or commands to be downloaded to the underwater vehicle.

## TRANSITIONS:

It is planned for this work to transition to submarines and other UUV operations.

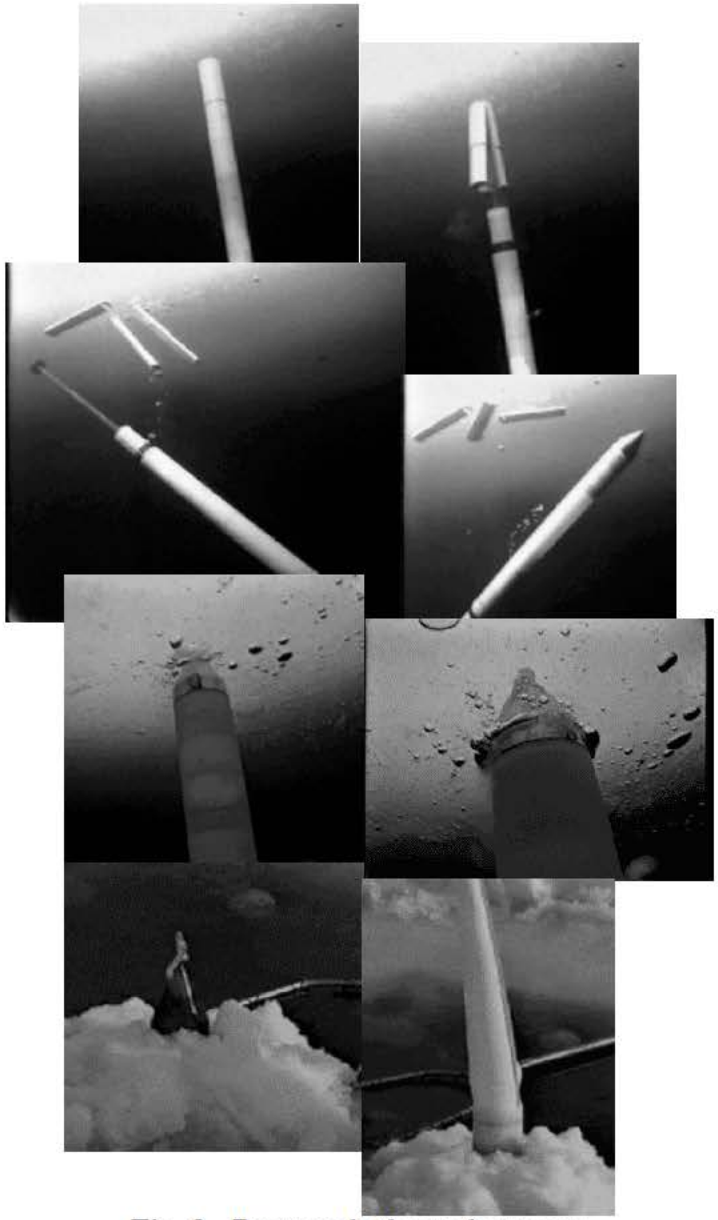

***Fig. 8. Buoy melt-through process.***

**RELATED PROJECTS:**

This project is closely related to other UUV projects that require the development of communication buoys, marker beacons, or launchers. Also, through the ALTEX project, it is related to other projects studying global climate change in the Arctic.

**PUBLICATIONS:**

Armen Bahlavouni, Douglas W. Andersen and Dr.Peter J. Stein, "Ice Penetrating Communication Buoy for Underwater Vehicles Operating in the Arctic," accepted for publication at Oceans/MTS 2001 conference proceedings, Honolulu, HI, November 6th – 8th, 2001.